3rd Montreal Industrial Problem Solving Workshop

Team 6: Truck Scheduling in Forestry

Coordinators: Louis-Martin Rousseau, Laurent D. Michel, Bernard Gendron
Students: Jean-François Audy, Nizar El Hachemi, Paul Khuong, Greg Rix, David Titley-Peloquin

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Setting

- Customer: Irving, New Brunswick (via FPInnovations-FERIC)
- Task: Schedule truck trips (full truck loads) in shifts to move wood from forests to mills
- Planning horizon: 1 work week (120 hours)
- Input: Stock (available at the beginning of the week), Demand (fulfilled by the end of week)
- Three aspects: Allocation, Routing & Scheduling

Always feasible (stock $\geq$ demand, sufficient time)

Figure: *We need more lumber!* (*Zug Zug*)

Instance

4 mills (sinks)
18 forests (sources)
6 wood types (products)

Figure: □ Mills, △ Forests

Instance

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18 forests (sources)
6 wood types (products)

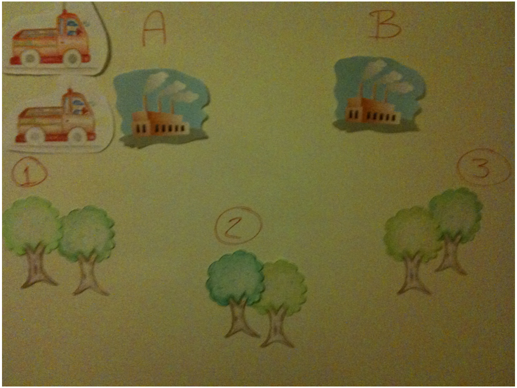
Products		MAPW	MHPW	SFGP	SFKP	SFPW	SFSL	SFSW	WPSL
Mills	DDM							115	
	GLT					10	600		
	R&S		5	5		80			27
	SXCP	2	5	5	25	25	5		
Forests	2071026						21		
	2071179						1		
	2072584								
	2072586								
	2073627					25			
	2073661								
	3070606								
	3070607						126		
	3070633								9
	3070787						5		
	3070954	2	10				18		9
	3071001						5		
	3071006						6		
	3072315						5		
	FH00577						19	115	
	NACKY			41	59	95	384		
	SH00379								9
	SXCPY						22		

Figure: Supplies and demands

Peculiarities

- 8-12h shifts, must begin and end at the same mill (base)
- Small unknown number of (un)loading machines per location
- Multi-criteria objective: minimize dead-heading? number of trucks? waiting time?

Our objective: minimize the total driving time first, then the waiting time, subject to a minimum number of hours per truck.



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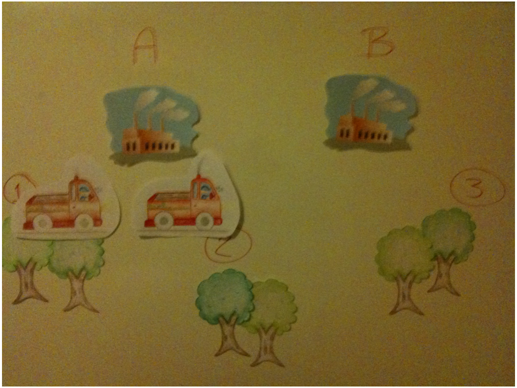

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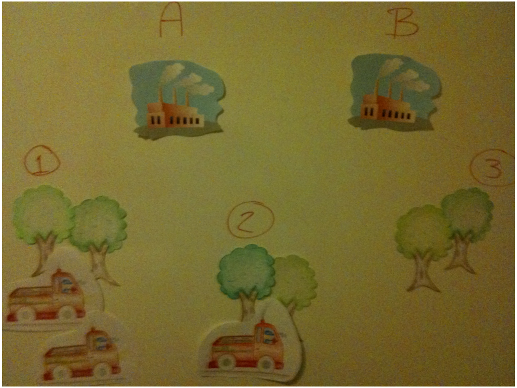

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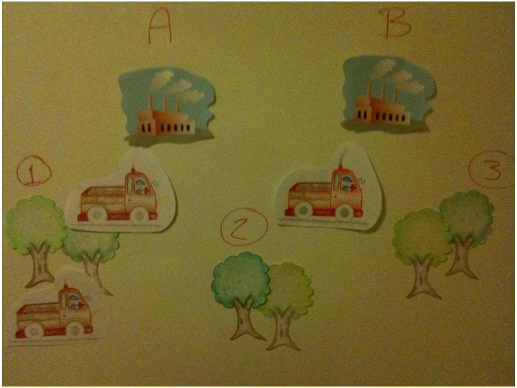

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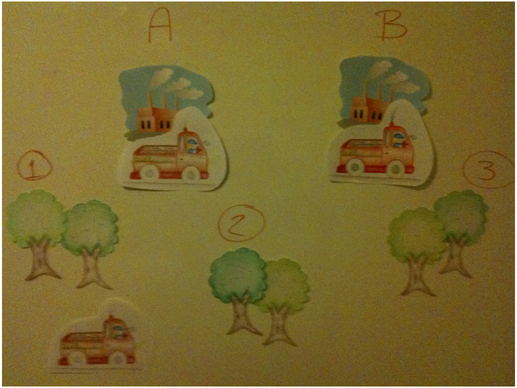

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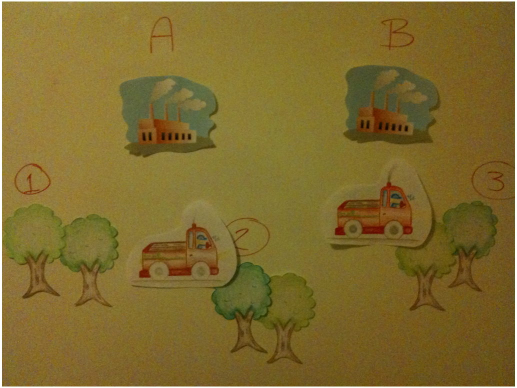

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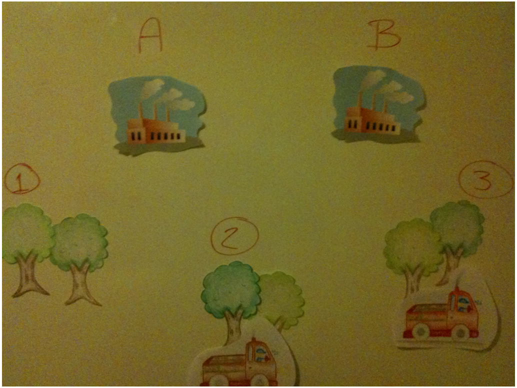

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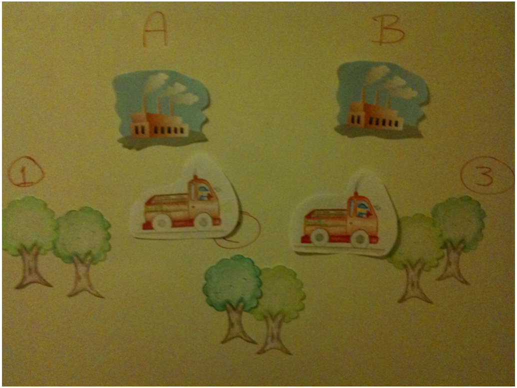

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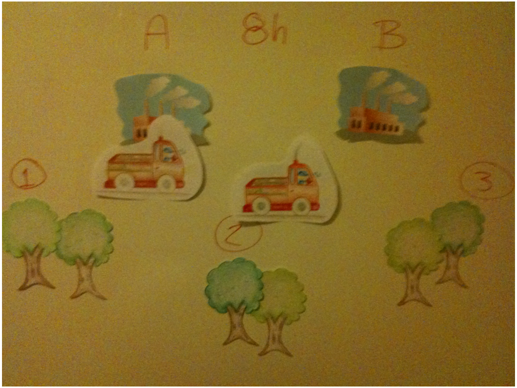

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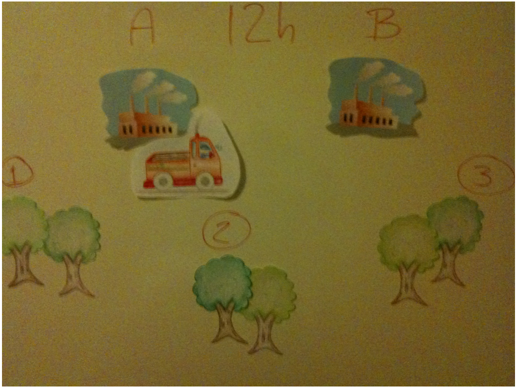


Existing methods

Current method: assign only Mill-Forest-Mill round-trips
MaxTour (Gingras et al, 2006): Clarke & Wright (1964),
merge round-trips $\longrightarrow$ reduce dead-heading
Motivation: MaxTour shows potential savings from more complex trips

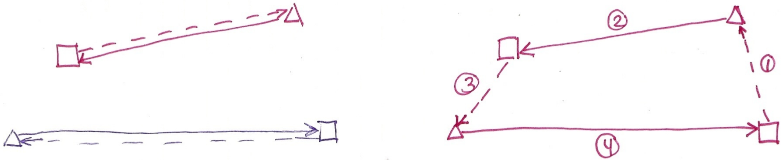


Figure: MaxTour savings

Local optimality of MaxTour

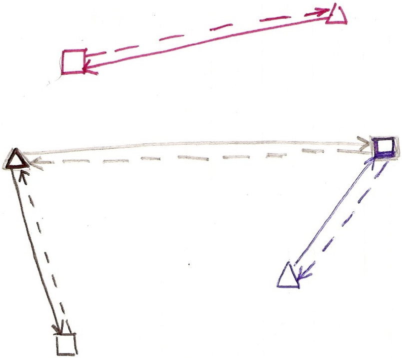


Figure: Carefully chosen atomic flows

Local optimality of MaxTour

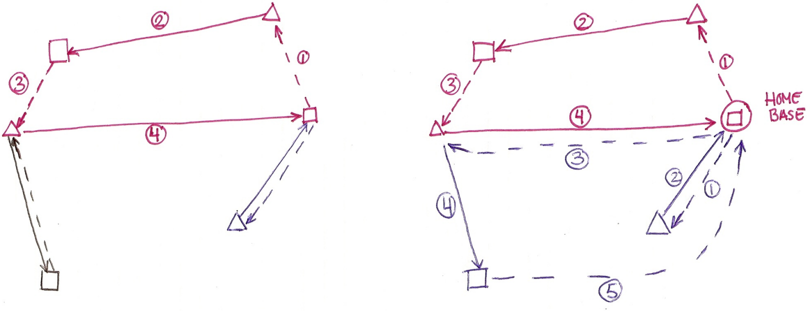


Figure: What happens when we consider shifts, home bases

Plan

1. Generate interesting, feasible shifts (CP, enumeration)
2. Select shifts (MIP)
3. Schedule shifts (CP)

COMET for modeling, CP, and for the glue.

Shift generation (Monday PM-Tuesday AM)

Simple problem, issue is pruning useless or redundant shifts

1. Generate any tour of duration between 8 and 12h (1M)
2. Only consider Forest$\longrightarrow$Mill and Mill$\longrightarrow$Forest arcs (60k)
3. Only repeat an arc insofar as required by the availability (resp. demand) of the commodity at the forest (resp. mill) (30k)
4. Break symmetries: place the lowest ordered mill at the start, etc. (17k)
5. Allow tours of duration between 8 and 11h (8k)

Shift selection (Tuesday AM)

Original formulation (choose tours and assign them to mills)

$$\min \sum_{m \in \text{Mills},\ c \in \text{Tours}} \text{time}[c] \cdot X_{bc}$$

s.t.

$$\sum_{b \in \text{Mills},\ c \in \text{Tours}} X_{bc} q_{cmp} \geq \text{Demand}[m, p] \quad \forall m \in \text{Mills}, p \in \text{Products}$$

$$\sum_{b \in \text{Mills},\ c \in \text{Tours}} X_{bc} q_{cfp} \leq \text{Stock}[f, p] \quad \forall f \in \text{Forests}, p \in \text{Products}$$

$$96 T_b \leq \sum_{c \in \text{Tours}} \text{time}[c] \cdot X_{bc} \leq 120 T_b \quad \forall b \in \text{Mills}$$

X_{bc} Integer, # of shifts c assigned to a truck homed at b

T_b Integer, # of trucks assigned to b

q_{clp} Constant, # of shipments of product p to/from location l in tour c

Working shift selection (Thursday PM)

$$\min \sum_{m \in \text{Mills}} \sum_{c \in \text{Tours}} \sum_{t \in [0,\text{nTruck}]} \text{time}[c] \cdot X_{bct}$$

such that

$$\sum_{b \in \text{Mills}} \sum_{c \in \text{Tours}} \sum_{t \in [0,\text{nTruck}]} X_{bct} q_{cmp} \geq \text{Demand}[m, p]$$

$$\forall m \in \text{Mills}, p \in \text{Products}$$

$$\sum_{b \in \text{Mills}} \sum_{c \in \text{Tours}} \sum_{t \in [0,\text{nTruck}]} X_{bct} q_{cfp} \leq \text{Stock}[f, p]$$

$$\forall f \in \text{Forests}, p \in \text{Products}$$

$$96 Y_{bt} \leq \sum_{c \in \text{Tours}} \text{time}[c] \cdot X_{bct} \leq 120 Y_{bt} \quad \forall b \in \text{Mills}, \ \forall t \in [0, \text{nTruck}]$$

X_{bct} Integer, number of shifts c assigned to truck t homed at b

Y_{bt} Boolean (equals 1 iff truck t homed at b is used)

q_{clp} Constant, number of shipments of product p to/from location l in c

Shift selection, take 2 (Tuesday PM)

SCIP unable to solve the formulation. Split into two phases:

1. Remove home bases and trucks $\Rightarrow$ Set Covering
2. Solve the original formulation, but only with the tours used in the solution found in the first phase

Set covering

Disregard bases, trucks in original problem:

$$\min \sum_{c \in \text{Tours}} \text{time}[c] \cdot X_c$$

s.t.

$$\sum_{c \in \text{Tours}} X_c q_{cmp} \geq \text{Demand}[m, p] \quad \forall m \in \text{Mills}, p \in \text{Products}$$

$$\sum_{c \in \text{Tours}} X_c q_{cfp} \leq \text{Stock}[f, p] \quad \forall f \in \text{Forests}, p \in \text{Products}$$

X_c Integer, number of shifts c

q_{clp} Constant, number of shipments of product p to/from location l in circuit c

Shift scheduling (Wednesday-Thursday)

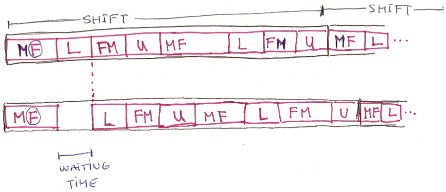
Jobs Each shift is a job (no precedence)

Act. For each trip in a shift,

1. Mill → Forest
2. Loading step
3. Forest → Mill
4. Unloading step

Strict precedence

Res. Loaders/unloaders per location, trucks (no preemption)



Experiment

Only one instance. Solution methods:

- Baseline (only round-trips), by hand
- MaxTour and round-trips, by hand
- Routing solution (Steps 1 and 2, no scheduling) [$\leq$ 1 minute]
- Full solver, Routing + Scheduling [$\approx$ 5 minutes to feasibility]

Benchmark

Savings in MaxTour (VS round-trips) come from reduced dead-heading.

Scenario	Total Time	%	Total Time Empty	%
Loops	3685.8	0.00%	1297.5	0.00%
MaxTour + Loops	3636.7	1.33%	1230.4	5.17%
Routing	3640.3	1.23%	1261.8	2.75%

Scheduling: waiting time of 111.3h (3.0% of total working time).

Base Mill	# trucks	# shifts
1	4	38
2	21	262
3	5	48
4	4	37

Loader profiles

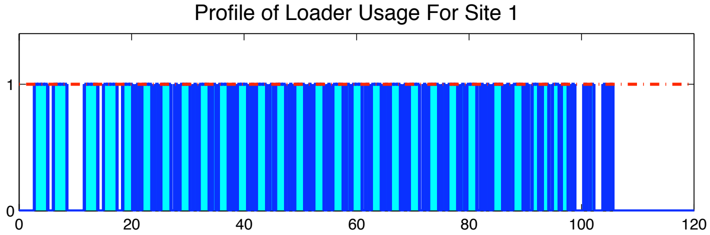


Figure: 1 loader

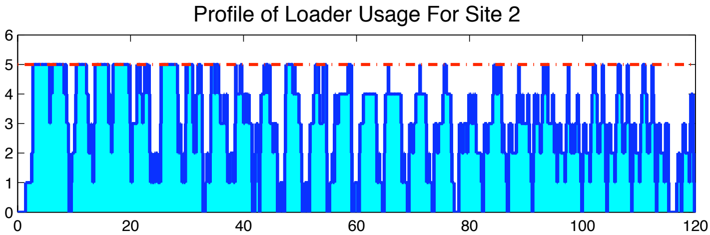


Figure: 5 loaders

Truck profiles

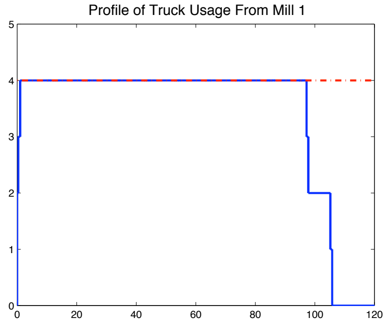


Figure: Normally loaded mill

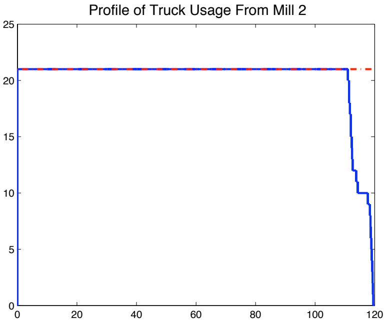


Figure: Most heavily loaded mill

Conclusion

- COMET allows decomposition with different methodologies
- Industrial partner provided a useful, complete data set
- Challenging problem! Possibilities:
  - Introduce feedback from scheduling to routing
  - Add random restart/LNS to reduce variance in scheduling
  - Solve both MIPs at once (with another solver)
- Looking forward to comparing with actual route assignments

Many thanks to Laurent, Louis-Martin, and Bernard, and to FPInnovations-FERIC!